ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5144

Enzymatic hydrolysis of phospholipids in cod flesh during storage in ice

T. Ohshima, S. Wada, and C. Koizumi

Original title: Hyozochu ni okeru Madaraniku Rinshishitsu no Kosoteki Kasuibunkai

In: Bull. Jpn. Soc. Sci. Fish. 50(1): 107-114, 1984

Original language: Japanese

Available from:

Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

1985

Fisheries & Oceans
LIBRARY

DEC 15 1986

BIBLIOTHÈQUE
Pêches & Océans

17 typescript pages

Secretary of State / Secrétariat d'État

90-00120/

MULTILINGUAL SERVICES DIVISION – DIVISION DES SERVICES MULTILINGUES

TRANSLATION BUREAU BUREAU DES TRADUCTIONS

LIBRARY IDENTIFICATION – FICHE SIGNALÉTIQUE

CTFAS 5144

Translated from - Traduction de	Into - En
Japanese	English

Author - Auteur

Toshiaki OSHIMA, Shun WADA, Chiaki KOIZUMI.

Title in English or French - Titre anglais ou français

Enzymatic Hydrolysis of Phospholipids in Cod Flesh during Storage in Ice.

Title in foreign language (Transliterate foreign characters)
Titre en langue étrangère (Transcrire en caractères romains)

Hyōzōchū ni okeru Madaraniku Rinshishitsu no Kōsoteki Kasuibunkai.

Reference in foreign language (Name of book or publication) in full, transliterate foreign characters.
Référence en langue étrangère (Nom du livre ou publication), au complet, transcrire en caractères romains.

Nihon Suisan Gakkai Shi.

Reference in English or French - Référence en anglais ou français

Bulletin of the Japanese Society of Scientific Fisheries.

Publisher - Éditeur	DATE OF PUBLICATION / DATE DE PUBLICATION			Page Numbers in original / Numéros des pages dans l'original
Nihon Suisan Gakkai.	Year / Année	Volume	Issue No. / Numéro	107 - 114
Place of Publication / Lieu de publication				Number of typed pages / Nombre de pages dactylographiées
Tokyo, Japan.	1984	50	1	17

Requesting Department / Ministère-Client: DFO

Branch or Division / Direction ou Division: SIPB

Person requesting / Demandé par:

Your Number / Votre dossier nº:

Date of Request / Date de la demande: March 28, 1985

Translation Bureau No. / Notre dossier nº: 1655869

Translator (Initials) / Traducteur (Initiales): KU / PS

MAY / MAI 28 1985

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

Canada

SEC 5-111 (84-10)

Secretary of State | Secrétariat d'État

MULTILINGUAL SERVICES DIVISION – DIVISION DES SERVICES MULTILINGUES

TRANSLATION BUREAU | BUREAU DES TRADUCTIONS

Client's No.–N° du client	Department – Ministère	Division/Branch – Division/Direction	City – Ville
	DFO	SIPB	Ottawa
Bureau No.–N° du bureau	**Language – Langue**	**Translator (Initials) – Traducteur (Initiales)**	
1655869	Japanese into English	KU / PS	MAY MAI 28 1985

Enzymatic Hydrolysis of Phospholipids in Cod Flesh during Storage in Ice

Toshiaki OHSHIMA,* Shun WADA,* and Chiaki KOIZUMI*

Enzymatic hydrolysis of phospholipids in cod flesh during storage in ice for 30 days were studied. The contents of phosphatidylcholine (PC) and phosphatidylethanolamine (PE) in the flesh decreased slowly during first 4 days of storage and then rapidly to 20 days. Thereafter, the decrease of the contents almost ceased. During storage for 30 days, 72.2% of PC and 71.8% of PE were hydrolyzed. Contrary to this, the content of free fatty acid (FFA) increased slowly during the first 4 days of storage and then rapidly up to 20 days.

Major PC in the cod flesh were those having fatty acid combinations of (C_{16}, C_{22}), (C_{18}, C_{20}), (C_{18}, C_{22}), and (C_{18}, C_{20}). Percentages of PC having the combinations of (C_{16}, C_{16}) and (C_{18}, C_{18}) increased rapidly during storage in ice, while those of (C_{18}, C_{20}), (C_{16}, C_{22}) and (C_{18}, C_{22}) decreased. In the case of PE, prominent fatty acid combinations were those of (C_{18}, C_{22}), (C_{18}, C_{22}), (C_{20}, C_{22}), (C_{22}, C_{22}), and (C_{20}, C_{20}). During storage, percentages of PE having the combinations of (C_{18}, C_{18}) and (C_{16}, C_{20}) increased, while those of (C_{20}, C_{22}) and (C_{22}, C_{22}) decreased.

From these results, it was suggested that the PC having fatty acid combinations of (C_{16}, C_{16}) and (C_{16}, C_{18}) and the PE having those of (C_{18}, C_{18}) and (C_{18}, C_{20}) were synthesized in the flesh during storage in ice from glycerylphosphorylcholine, glycerylphosphorylethanolamine and FFA which had been produced from PC and PE with enzymatic hydrolysis.

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

Since Dyer et al[1-3] pointed out the relation between 107
deterioration of frozen fish and hydrolysis of phospholipids, many studies have been done on hydrolysis of phospholipids in fish stored at low temperatures. These studies have made it clear that

1) Phosphatidylcholine (PC) is hydrolyzed faster than phosphatidylethanolamine (PE)[4-9];

2) PC and PE are hardly hydrolyzed after 70-80% has been hydrolyzed;[7,10,11]

* 東京水産大学食品生産化学科 (Tokyo University of Fisheries, Konan-4, Minato, Tokyo 108, Japan).

3) Hydrolysis of phospholipids proceeds most quickly at $-4^{\circ}C$[11] or $-5^{\circ}C$.[12]

However, in most cases, the reasons for these results were not made clear. In our previous report,[6] we studied changes of PC and PE in cod flesh stored at $-16^{\circ}C$ by analyzing the molecular types, and announced that constitutive fatty acids of PC and PE are selectively hydrolyzed.

In this report, we discuss in detail changes of phospholipids in cod flesh stored in ice, using a method given in the previous report[13] for estimating fatty acid combinations of PC and PE in fish. We try to make clear that differences of enzymatic hydrolysis of phospholipids in fish depend on storing temperatures. We guess that PC and PE are synthesized from free fatty acid (FFA), glyceryl-phosphorylcholine (GPC), and glycerylphosphorylethanolamine, which have been produced by hydrolysis.

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

Experimental

Sample of fish Three cods (Gadus morhua), weighing 5.7kg on average, bought at the Tokyo Central Wholesale Market in January, 1983, were used. They were filleted, and each fillet was cut in half: head and tail parts. Each part was put in a polyethylene bag with ice and kept in a low temperature room at $4^{\circ}C$. Sampling was performed as shown in Fig. 1, in order to minimize the effects of individual differences.

Lipid extraction The surface of the fillets was removed in order to prevent the admixture of oxidized lipids. The ordinary muscle

ground and the total lipid (TL) was extracted by the Bligh and Dyer Method.[14]

Fractionation and analysis methods of lipids The fractionation of lipids, thin layer chromatography (TLC), high potential liquid chromatography (HPLC) of polar lipid (PL), analysis of fatty acid compositions, and estimation of fatty acid combinations of PC and PE, are the same as in the previous report.[6] However, the method of addition of hydrogen to 1,2-diglyceride was improved in this report: the pressure of hydrogen was increased to 0.8kg/cm^2 in order to speed up the process.

Results and Discussion

Changes of lipid contents Fig. 2 shows changes of lipid contents during storage. The lipid content of the samples was 727mg/100g on the 0th day, and about 83% of it was PL. TL and PL showed hardly any change during the first 2 days of storage in ice, but they started decreasing gradually on the 4th day. On the other hand, non-polar lipid (NL) increased gradually. The reason why PL decreases and NL increases during storage is that, as pointed out in the previous report,[6] FFA, produced by hydrolysis of PL, is fractionated into NL. The reason why TL decreases is that GPC,[15] produced by hydrolysis, is water-soluble and removed from the lipid fraction. Lovern et al[10] showed that hydrolysis of phospholipids in cod flesh stored in ice is relatively slow up to 2 weeks, and that it proceeds rapidly after that. In this study, the result was almost the same as Lovern et al's - that is, PL decreases rapidly after the 10th day of storage. Also, the volumes of PL and NL and the pattern of HPLC (which will

be stated later) showed hardly any change up to the 2nd day. Therefore, it is considered that the hydrolysis of phosphōlipids is quite slow up to the 2nd day.

Changes of fatty acid compositions of TL, PL, NL, and FFA

Tables 1-4 show changes in the fatty acid compositions of TL, PL, NL, and FFA during storage. In TL, C22:6, C16:0, C20:5, C18:1, C18:0, and C20:4, were the main constitutive fatty acids. Among these, C22:6 was most abundant (31,3%). During storage, C22:6 decreased, C20:5 and C18:1 increased, and C16:0 hardly changed. 109

The main constitutive fatty acids of PL are almost the same as those of TL. This is because, as shown in Fig. 2, about 83% of TL is composed of PL. The compositional percentage of C20:4 and C22:6 decreased during storage, but C20:5 increased up to the 10th day, and C16:0 increased during the whole storage period.

Among constitutive fatty acids of NL, compositional percentage of C22:6, C16:0, C20:5, and C18:1 were high. The compositional percentage of C22:6 and C20:5 increased, and those of C16:0 and C18:1 decreased during storage.

Fatty acids which were proportionally high in FFA were C22:6, C16:0, C20:5, and C18:1, which were the same as in NL. Among these, the compositional percentages of C22:6 and C20:5 increased and that of C16:0 decreased, but C18:1 hardly changed. 110

C22:6 of PL decreased during storage, but C22:6 of FFA increased. Therefore, it is considered that the decrease of C22:6 is due to enzymatic hydrolysis, not to oxydation.

Changes of compositions of NL and PL Compositional percentages of each lipid class, obtained by silicic acid TLC and densitometry, were converted into amount (mg) per 100g of fish flesh, using the

NL and PL contents shown in Fig. 2. Fig. 3 and 4 show their changes during storage.

In NL, six kinds of lipid classes were separated into 5 spots: (hydrocarbon (HC) + sterol ester (SE)), triglyceride (TG), (sterol (ST) + diglyceride (DG)), FFA, and unknown (U.K.). Among these, FFA increased during the whole period of the storage, especially rapidly from the 4th to the 20th day, and slowly after the 20th day. Under the conditions of this TLC, separation of HC and SE was not sufficient. However, the increase during storage of the spot due to SE was obvious. Therefore, it can be said that the increase of (HC+SE) during storage is mainly due to the increase of SE. Also, the decrease of (ST+DG) is due to the decrease of ST, judging from the results of TLC. The content of TG was about 20mg/100g, and no big change was observed during storage.

In PL, 6 kinds of lipid classes were separated into 6 spots by TLC. They are (PC + lysophosphatidylethanolamine (LPE)), PE, sphingomyelin (SPM), phosphatidylserine (PS), lysophosphatidylcholine (LPC), and unknown (U.K.). As shown in the previous report,[6] most of the (PC+LPE) spot was occupied by PC. PC decreased rapidly after the 4th day, and especially from the 10th to the 20th day. PE and PS decreased as well as PC, but other lipid classes hardly changed.

The tendency of increase of FFA in Fig. 3 corresponds well with the tendency of decrease of PC and PE in Fig. 4. Also, there was no change in the amount of TG during storage. Therefore, it is considered that FFA was generated by hydrolysis of PC, PE, and PS. However, the accumulated amount of FFA in cod flesh stored at -16°C

was 253mg/100g, when hydrolysis of PC reached 72.5% (24th week).[6] In the case of storage in ice, even when hydrolysis of PC reached 72.2% (30th day), the amount of FFA was 181mg/100g in this study. It was about 70mg/100g less than for storage in a freezer. On the other hand, (HC+SE) was 113mg/100g on the 30th day. It increased 85mg/100g from the 0th day. These results indicate that part of the FFA which had been produced by hydrolysis was ester-combined with ST, and generated SE. Lovern et al[11] also pointed to the increase of SE during storage in ice.

As reported in the previous study,[5] in cod frozen and stored at -16°C, PC is hydrolyzed more quickly than PE. In the case of storage in ice in this study, the remaining percentages of PC and PE on the 30th day were 27.8% and 28.1%, respectively, of those on day 0. There was no significant difference between them. However, on the 20th day, PC was 33.4% and PE 36.1%. The hydrolysis of PC was a little faster. The decrease of PC and PE and the increase of FFA became slow after the 20th day. Therefore, it seems that in the case of storing cod in ice, as has been pointed out in the studies conducted so far, hydrolysis of PC and PE stops apparently after 70-80% have been hydrolyzed.

Changes of HPLC patterns of PL Fig. 5 shows changes of HPLC patterns of PL during storage in ice. In the samples on day 0, two big PE and PC peaks and two small LPE and SPM peaks appeared. There were no big changes in the shapes of these peaks up to the 4th day, but the ratio of area of the PC peak to PE became smaller and smaller. This is because, as shown in Fig. 4, the speeds of hydrolysis of PC and PE are different. On the 10th day of storage, on the back of the PC peak (at around 13 min.),

a shoulder emerged, which became an independent peak on the 20th and 30th day (at about 15 min.). The content of the peak showed a single spot in silicic acid secondary TLC and became positive in Dragendorff reagent[16] and Dittmer reagent.[17] Therefore, it was identified as PC. This means that PC with different fatty acid combinations has been newly produced during storage.

Changes of fatty acid compositions in PC and PE Tables 5 and 6 show changes of fatty acid compositions in PC and PE during storage. In PC, C22:6, C16:0, C20:5, and C18:1 were the main fatty acids. Among these, C22:6 occupied 89.6% of fatty acids whose carbon number is 22 (C22), C16:0 occupied 84.5% of C16, C20:5 79.0% of C20, and C18:1 82.6% of C18. Among these fatty acids, C22:6 and C20:5 decreased, but C16:0 and C18:1 increased during storage.

In fatty acids of PE, C22:6, C20:5, C18:1, C18:0, and C16:0 were abundant. C22:6 was most abundant in C22, C20:5 in C20, C16:0 in C16, and C18:1 and C18:0 in C18. The compositional percentage of C20:5 and C22:6 decreased, and that of C16:0 and C18:0 increased during storage.

Fatty acid combinations of PC and PE, and their changes in compositional percentage Tables 7 and 8 show saturated fatty acid compositions of PC after hydrogenation, and PC compositions based on their total carbon (TC) in fatty acyl chains. In the 0th day samples, PC compositions are high in TC 38, 36, 40, 42, 44, and 34. This corresponds well with PC compositions in cod in the previous report.[6] 112

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

From the results in Tables 7 and 8, fatty acid combinations of PC were estimated according to the method of the previous study.[13] They are shown in Table 9, together with the changes in them during storage. PC with combinations of (C16, C22), (C16, C20), (C18, C22), (C18, C20), are the main components, and these are quite similar to those in the previous report.[6] From the fatty acid compositions in Table 5, it is considered that most of the combinations consist of (C16:0, C22:6), (C16:0, C20:5), (C18:1, C22:6), and (C18:1, C20:5).

After the 4th day of storage, the percentages of PC having the combinations of (C16:0, C16:0) and (C16:0, C18:1) increased remarkably, and PC of (C16:0, C20:5), (C16:0, C22:6), and (C18:1, C22:6) decreased slightly. PC of (C22:6, C22:6) and (C20:5, C22:6) decreased temporarily on the 4th day, but increased after that. Such changes of PC compositions during storage indicate that hydrolysis of PC happens selectively on the constitutive fatty acid. However, the increase of (C16:0, C16:0) and (C16:0, C18:1) cannot be explained only by selective hydrolysis. As mentioned before, a new peak appeared on the 20th and the 30th day of storage on the chromatogram of HPLC. If the content of the peak is PC with combinations of (C16:0, C16:0) and (C16:0, C18:1), (a separate report will be announced on this matter), the remarkable increase of (C16:0, C16:0) and (C16:0, C18:1) of PC during storage can be easily explained by assuming that they were newly produced. That is, if we assume that the PC with new combinations of fatty acids is re-constructed from GPC and FFA which have been generated by hydrolysis of PC during storage, the remarkable increase of (C16:0, C16:0) and (C16:0, C18:1) during storage is easily explained. Furthermore, if we

assume this kind of new formation of PC, it is easy to tell that the stopping of hydrolysis of phospholipids in fish stored so far at low temperatures when phospholipids are reduced to 20-30% of the original amount is apparent. That is, after the hydrolysis progresses and GPC and FFA have accumulated to a certain degree, PC is re-synthesized. Decomposition and formation are balanced in this way. However, in the case of the storage of cod flesh at -16°C,[6] this kind of re-synthesis of PC was not observed. Further studies are needed on this subject.

Tables 10 and 11 show saturated fatty acid compositions of 113
PE, and PE compositions based on TC. The samples on the 0th day show that PE of TC 40, 38, 42, 44, 36, and 34 are the main components. Comparing with the compositions of PC, the compositions of PE are characteristically high in bigger TC. Table 12 show possible fatty acid combinations of PE, estimated from the results in Tables 10 and 11, as in the case of PC, and their changes during storage. Most PE have combinations of (C18, C22), (C16, C22), (C20, C22), (C22, C22), and (C20, C20). From fatty acid compositions in Table 10, it is guessed that PE of (C18:1 or C18:0, C22:6), (C16:0, C22:6), (C20:5, C22:6), (C22:6, C22:6), and (C20:5, C20:5) are most 114
abundant. During storage, the percentage of PE with combinations of (C16:0, C18:1 or C18:0) and (C16:0, C20:3) increased, and (C20:5, C22:6) and (C22:6, C22:6) decreased. These changes are almost the same as in PC.

PC of (C16, C16) and (C16, C18), and PE of (C16, C18) and (C16, C20), which existed to a small extent in fresh cod, increased

remarkably during storage in ice. Therefore, in this study, we guessed the possibility that they were synthesized. However, at the same time, we cannot deny the possibility that bacteria might have contributed to the syntheses. Further studies on this matter are needed.

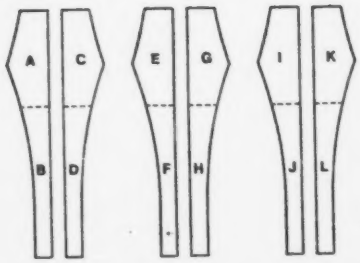

Fig. 1. Cod fillets of A and F, C and J, E and L, G and B, I and H, and K and D were used for lipid extractions after storage for 0, 2, 4, 10, 20, and 30 days in ice, respectively.

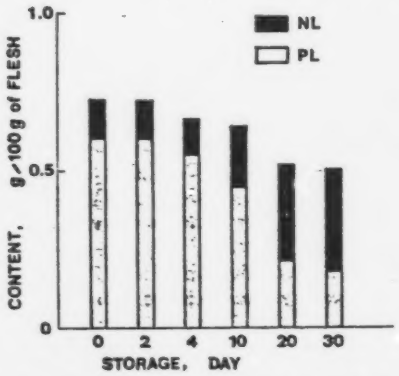

Fig. 2. Changes in the contents of total lipid, polar lipid (PL) and non-polar lipid (NL) in cod during storage in ice.

Table 1. Changes in fatty acid compositions of TL of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.0	1.0	1.0	1.2	1.0	0.9
15:0	0.3	0.2	0.3	0.2	0.3	0.2
16:0	18.2	17.1	18.0	18.4	18.4	17.9
:1	3.8	4.1	4.0	4.4	4.1	3.1
:2	0.4	0.4	0.3	0.3	0.4	0.2
17:0	0.5	0.6	0.2	0.3	0.3	0.2
18:0	4.7	4.8	4.5	5.3	4.7	5.9
:1	13.5	13.8	13.8	14.6	14.1	15.1
:2	0.5	0.8	0.5	0.8	0.6	0.6
:3	1.2	1.2	1.1	1.7	1.2	2.2
20:0	0.2	0.2	0.1	tr	tr	—
:2	0.3	0.3	0.3	0.5	0.3	0.3
:4	4.3	4.2	3.8	3.9	3.9	4.3
:5	15.7	16.0	18.1	19.7	17.3	17.8
22:4	0.5	0.5	1.0	0.4	1.4	0.9
:5	3.2	2.7	3.3	1.7	3.2	2.5
:6	31.3	31.7	29.4	26.2	28.5	27.6
23:0	0.3	0.4	0.2	0.3	0.2	0.4

Table 2. Changes in fatty acid compositions of PL of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.0	0.4	1.0	1.3	1.4	1.6
15:0	0.2	0.1	0.3	0.3	0.5	0.4
16:0	19.7	16.1	19.8	21.1	29.9	32.7
:1	3.6	2.5	3.6	3.4	4.3	3.7
:2	0.3	0.3	0.3	0.3	0.3	0.2
17:0	0.4	0.3	0.3	0.3	0.3	0.2
18:0	4.9	6.2	5.3	5.8	6.5	8.3
:1	13.6	15.2	13.9	14.3	14.0	15.4
:2	0.5	0.5	0.6	0.6	0.5	0.5
:3	1.2	1.4	0.9	1.6	1.0	2.1
20:0	0.1	0.1	tr	0.1	0.1	—
:2	0.2	0.2	0.2	0.2	0.1	0.1
:4	4.2	4.3	3.7	3.7	3.1	2.8
:5	15.1	12.4	16.5	17.6	11.4	9.9
22:4	0.9	0.4	0.5	0.7	0.5	1.1
:5	2.7	3.8	2.9	2.1	2.6	1.6
:6	30.9	35.5	30.0	26.2	23.8	19.2
23:0	0.4	0.3	0.2	0.3	0.2	0.1

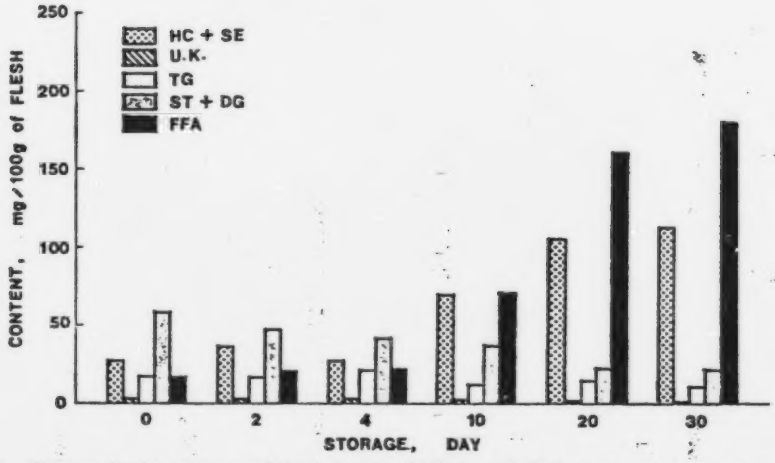

Fig. 3. Changes in the contents of lipid classes of NL in cod flesh during storage in ice. HC, hydrocarbon; SE, sterol ester; U.K., unknown; TG, triglyceride; ST, free sterol; DG, diglyceride; FFA, free fatty acid.

Table 3. Changes in fatty acid compositions of NL of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.4	0.7	1.6	1.4	0.9	1.0
15:0	0.3	0.1	0.3	0.1	0.2	0.1
16:0	17.6	16.2	15.5	14.7	12.5	13.2
:1	5.8	5.1	7.5	4.2	4.3	3.8
:2	0.4	0.2	0.5	0.2	0.4	tr
17:0	0.4	0.2	0.2	0.3	0.2	tr
18:0	4.1	4.4	3.2	4.1	3.8	4.3
:1	15.3	18.5	16.3	13.3	14.2	14.8
:2	0.9	0.6	0.7	1.0	0.6	0.8
:3	2.2	3.7	2.5	2.1	1.1	1.8
20:0	0.2	0.1	0.1	0.1	0.1	tr
:2	1.7	0.6	1.5	2.9	0.5	0.8
:4	4.3	4.9	3.8	4.4	4.3	4.6
:5	16.6	14.6	20.9	22.3	20.9	21.8
22:4	tr	0.5	1.0	1.0	1.1	0.8
:5	2.9	3.6	3.0	2.6	3.6	2.9
:6	25.2	25.3	21.0	24.5	31.0	28.7
23:0	0.7	0.7	0.5	0.8	0.3	0.5

Table 4. Changes in fatty acid compositions of FFA of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.4	1.5	1.3	0.8	0.9	1.0
15:0	0.3	0.3	0.3	0.1	0.3	0.1
16:0	19.3	19.6	17.9	11.8	14.2	12.6
:1	4.6	4.7	4.4	2.5	3.5	3.0
:2	0.3	0.3	0.4	0.2	0.2	0.2
17:0	0.1	0.1	0.2	0.3	0.1	0.2
18:0	4.2	3.9	3.4	2.2	2.5	2.5
:1	12.2	12.4	12.1	11.5	11.9	13.1
:2	0.6	0.5	0.6	0.6	0.5	0.6
:3	1.4	1.2	0.9	1.2	0.7	1.3
20:0	0.1	0.1	0.1	tr	0.1	tr
:2	0.5	0.9	0.6	0.6	2.2	0.5
:4	3.7	3.9	3.6	4.0	3.7	3.9
:5	22.3	23.4	27.1	28.2	20.2	25.6
22:4	0.8	0.5	0.4	0.4	1.1	0.6
:5	2.9	2.6	2.9	3.2	4.0	2.0
:6	25.5	24.1	23.9	32.3	34.0	32.2
23:0	—	—	—	—	—	0.6

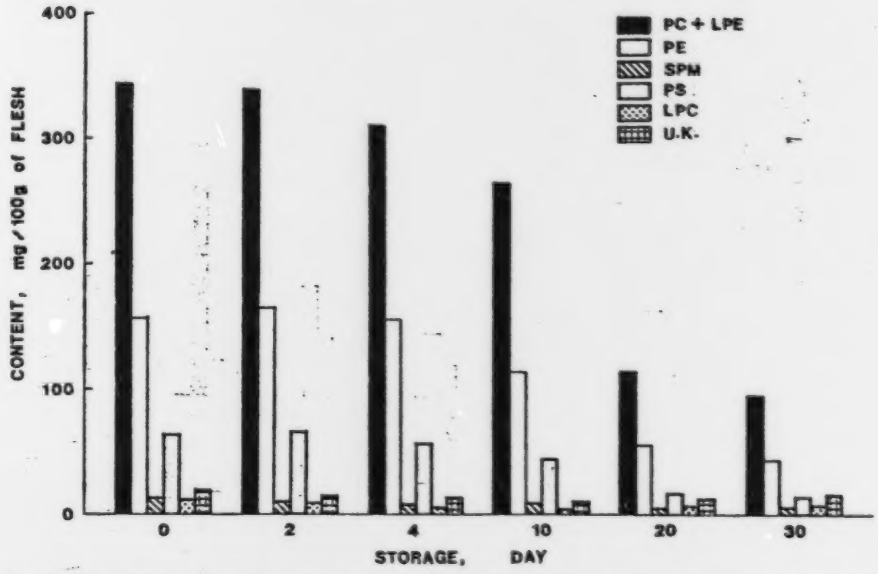

Fig. 4. Changes in the contents of lipid classes of PL in cod flesh during storage in ice. PC, phosphatidylcholine; LPE, lysophosphatidylethanolamine; PE, phosphatidylethanolamine; SPM, sphingomyelin; PS, phosphatidylserine; LPC, lysophosphatidylcholine; U.K., unknown.

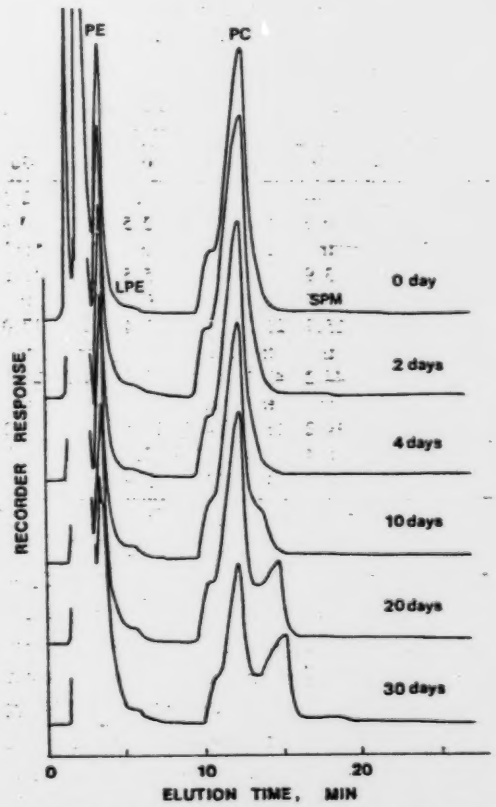

Fig. 5. Changes in the elution patterns of phospholipids of cod in HPLC during storage in ice.

Table 5. Changes in fatty acid compositions of PC of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.2	1.1	1.4	1.7	1.6	1.8
15:0	0.3	0.3	0.3	0.2	0.4	0.4
16:0	21.8	20.9	25.7	25.2	31.3	35.0
:1	3.8	3.9	3.9	3.8	3.9	3.3
:2	0.2	0.3	0.2	0.3	0.3	0.3
17:0	0.3	0.4	0.2	0.3	0.3	0.3
18:0	0.9	1.0	1.0	1.7	2.2	4.2
:1	9.5	10.2	9.3	11.4	11.0	13.2
:2	0.7	0.4	1.1	0.5	0.4	0.5
:3	0.4	0.5	0.4	0.8	0.7	1.9
20:0	0.2	0.2	0.2	0.1	0.1	tr
:2	1.0	0.3	2.3	1.0	1.6	0.2
:4	3.6	4.0	3.2	3.4	2.9	2.8
:5	18.1	19.0	17.8	20.7	13.4	12.2
22:4	0.6	0.2	0.9	0.9	0.5	1.0
:5	3.3	2.8	3.0	2.1	2.2	1.3
:6	33.7	34.1	28.5	25.6	27.2	21.6
23:0	0.5	0.5	0.3	0.3	tr	tr

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

Table 6. Changes in fatty acid compositions of PE of cod flesh during storage in ice

(wt%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	0.2	0.2	0.2	0.5	0.7	0.9
15:0	0.2	0.3	0.3	0.2	0.6	0.5
16:0	6.6	6.8	7.4	10.1	13.8	17.1
:1	1.4	1.5	1.7	2.1	3.3	3.0
:2	tr	tr	tr	0.2	0.3	0.3
17:0	0.3	0.3	0.2	0.2	0.3	0.4
18:0	6.8	8.3	6.7	7.9	9.4	10.1
:1	15.3	16.1	15.4	14.5	16.2	16.9
:2	0.7	0.7	0.7	0.7	0.8	0.9
:3	1.8	1.9	1.6	2.3	1.6	2.4
20:0	0.1	0.2	0.1	tr	tr	tr
:2	0.2	0.5	0.2	2.1	tr	tr
:4	4.0	4.1	3.6	3.7	4.0	3.6
:5	15.5	13.6	15.1	15.6	11.1	10.8
22:4	tr	tr	0.2	0.3	0.1	0.7
:5	3.4	3.5	4.1	3.1	2.9	2.5
:6	43.5	41.5	42.1	35.7	33.7	29.8
23:0	tr	0.5	0.4	0.8	1.4	tr

Table 7. Changes in fatty acid compositions of the PC after hydrogenation

(mol%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.7	1.5	2.0	2.2	2.4	2.4
15:0	0.4	0.4	0.5	0.2	0.6	0.4
16:0	32.0	30.3	36.6	36.0	42.7	43.8
17:0	0.3	0.5	0.5	0.3	0.7	0.4
18:0	12.4	13.1	12.5	15.0	14.5	18.3
19:0	0.2	0.2	0.2	0.2	0.2	0.2
20:0	21.4	22.0	20.7	22.2	14.9	14.9
21:0	0.3	0.3	—	—	0.3	0.3
22:0	31.3	31.6	27.0	24.0	23.7	19.3

Table 8. Changes in PC compositions based on their total carbon in fatty acyl chains after hydrogenation

(mol%)

TC*	Storage, day					
	0	2	4	10	20	30
30	—	—	—	tr	1.0	2.1
32	0.5	0.6	0.6	2.5	11.1	20.9
33	tr	tr	tr	tr	tr	tr
34	3.9	3.8	3.7	5.5	9.1	13.5
35	0.7	0.4	0.5	0.4	tr	tr
36	25.7	25.5	27.4	27.4	20.0	17.0
37	tr	tr	tr	tr	tr	tr
38	44.2	43.1	43.4	37.5	34.2	24.1
39	tr	tr	tr	tr	tr	tr
40	14.2	15.1	14.5	15.5	13.9	12.2
42	6.4	7.0	6.4	7.2	6.2	6.3
44	4.4	4.6	3.5	3.9	4.4	3.8

* Total carbon in fatty acyl chains.

Table 9. Possible fatty acid combinations of the PC and changes in their percentages during storage in ice

(mol%)

TC	Combination of fatty acid	Storage, day					
		0	2	4	10	20	30
30	C_{14}, C_{16}	—	—	—	tr	1.0	2.1
32	C_{16}, C_{16}	0.6	0.7	1.3	3.4	11.9	21.1
34	C_{13}, C_{19}	—	—	—	—	—	0.1
	C_{16}, C_{18}	4.0	3.8	4.5	6.4	10.0	13.6
	C_{17}, C_{17}	—	0.1	—	—	—	—
35	C_{14}, C_{21}	0.1	—	—	—	—	—
	C_{15}, C_{20}	0.1	—	—	—	—	—
	C_{16}, C_{19}	0.3	0.2	0.7	0.8	—	—
	C_{17}, C_{18}	0.2	0.2	—	—	—	—
36	C_{14}, C_{22}	2.6	2.7	1.2	1.2	1.0	1.7
	C_{15}, C_{21}	0.2	0.5	—	—	—	tr
	C_{16}, C_{20}	21.9	20.6	24.8	23.1	17.9	11.2
	C_{17}, C_{19}	—	0.2	0.1	0.1	—	—
	C_{18}, C_{18}	0.9	1.4	1.3	3.1	1.2	4.2
38	C_{16}, C_{22}	35.9	34.3	36.6	30.5	29.0	17.4
	C_{17}, C_{21}	0.1	0.2	—	—	0.4	0.6
	C_{18}, C_{20}	8.1	8.5	6.2	6.4	4.4	6.0
	C_{18}, C_{18}	0.1	0.1	0.6	0.6	0.4	0.2
40	C_{18}, C_{22}	10.4	10.8	10.7	9.8	10.4	8.1
	C_{19}, C_{21}	0.2	0.1	—	—	0.9	0.3
	C_{20}, C_{20}	3.6	5.2	3.8	5.7	2.6	3.7
42	C_{20}, C_{22}	6.0	6.7	4.7	5.4	4.4	5.8
	C_{21}, C_{21}	0.4	—	—	—	1.8	0.5
44	C_{22}, C_{22}	4.1	4.4	1.3	1.6	2.6	3.2

Table 10. Changes in fatty acid compositions of the PE after hydrogenation

(mol%)

Fatty acid	Storage, day					
	0	2	4	10	20	30
14:0	1.0	0.8	0.3	0.8	0.8	1.3
15:0	tr	tr	tr	0.2	0.7	0.6
16:0	11.2	10.8	11.2	15.3	18.2	22.8
17:0	0.3	0.2	0.2	1.1	2.8	3.6
18:0	25.8	25.8	23.5	24.5	23.5	25.8
19:0	0.4	0.3	0.3	0.3	0.4	0.3
20:0	19.8	19.9	20.1	22.1	17.3	17.1
21:0	0.5	0.4	0.5	0.3	0.5	0.4
22:0	41.0	41.8	42.8	35.4	35.8	28.1

Table 11. Changes in PE compositions based on their total carbon in fatty acyl chains after hydrogenation

(mol%)

TC	Storage, day					
	0	2	4	10	20	30
32	—	—	—	0.3	2.8	4.8
34	3.2	0.8	1.1	2.0	5.0	9.7
36	8.7	8.0	8.4	11.7	9.4	13.4
38	27.2	27.8	27.2	28.8	28.3	28.2
40	35.5	37.5	34.3	31.3	31.7	26.5
42	13.1	13.6	14.0	14.8	12.1	10.7
44	12.3	12.4	15.1	11.1	10.8	6.8

Table 12. Possible fatty acid combinations of the PE and changes in their percentages during storage in ice

(mol%)

TC	Combination of fatty acid	Storage, day					
		0	2	4	10	20	30
32	C_{16}, C_{16}	—	—	—	1.1	3.0	5.0
34	C_{16}, C_{18}	3.2	1.0	1.2	2.7	4.0	8.0
	C_{17}, C_{17}	—	—	—	—	1.2	1.9
36	C_{14}, C_{22}	1.5	0.7	0.1	—	—	0.1
	C_{16}, C_{20}	0.4	0.5	1.8	4.4	3.6	5.8
	C_{18}, C_{18}	6.8	6.9	6.5	7.3	5.9	7.6
38	C_{16}, C_{22}	18.4	19.4	19.0	18.4	20.1	18.8
	C_{17}, C_{21}	0.1	0.1	0.1	0.7	1.3	1.4
	C_{18}, C_{20}	8.7	8.3	7.9	9.4	6.5	7.7
	C_{18}, C_{18}	tr	0.1	0.1	0.4	0.3	0.3
40	C_{18}, C_{22}	25.7	27.7	24.7	21.1	23.5	19.3
	C_{19}, C_{21}	0.9	0.6	0.7	1.0	0.6	0.7
	C_{20}, C_{20}	9.0	9.2	8.9	9.2	7.5	6.4
42	C_{20}, C_{22}	12.8	12.9	13.3	13.7	11.1	9.6
	C_{21}, C_{21}	0.3	0.7	0.7	1.1	1.0	1.1
44	C_{22}, C_{22}	12.0	11.8	14.6	9.8	9.5	5.3

References

1) W. J. DYER: *Food Res.*, 16, 522–527 (1951).
2) W. J. DYER and M. L. MORTON: *J. Fish. Res. Bd. Canada*, 13, 129–134 (1956).
3) W. J. DYER, M. L. MORTON, D. I. FRASER, and E. G. BLIGH: *J. Fish. Res. Bd. Canada*, 13, 569–579 (1956).

4) T. OSHIMA, C. KOIZUVI: Nissuishi (Bulletin of the Japanese Society of Scientific Fisheries), 49, 1205-1212 (1983).

5) T. OSHIMA, S. WADA, C. KOIZUMI: ibid., 49, 1213-1219 (1983).

6) T. OSHIMA, S. WADA, C. KOIZUMI: ibid., 49, 1397-1404 (1983).

7) E. G. BLIGH and M. A. SCOTT: *J. Fish. Res. Bd. Canada*, 23, 1025–1036 (1966).
8) R. J. BRADDOCK and L. R. DUGAN, JR.: *J. Food Sci.*, 37,426–429 (1972).

9) N. TSUKUDA: Tokai Suikenhó (Bulletin of the Tokai Regional Fisheries Research Lab.), n.87, 1-6 (1976).

10) J. A. LOVERN, J. OLLEY, and H. A. WATSON: *J. Sci. Food Agric.*, 10, 372–337 (1959).
11) J. A. LOVERN and J. OLLEY: *J. Food Sci.*, 27, 551–559 (1962).

12) K. HANAOKA, M. TOYOMIZU: Nissuishi (Bulletin of the Japanese Society of Scientific Fisheries), 45, 465-468 (1979).

13) T. OHSHIMA, S. WADA, and C. KOIZUMI: *Bull. Japan. Soc. Sci. Fish.*, 49, 123–130 (1983).
14) E. G. BLIGH and W. J. DYER: *Can. J. Biochem. Physiol.*, 37, 911–917 (1959).
15) J. OLLEY and J. A. LOVERN: *J. Sci. Food Agric.*, 11, 644–652 (1960).
16) R. MUNIER and M. MASHEBOEUF: *Bull. Soc. Chim. Biol.*, 33, 846 (1951).
17) J. C. DITTMER and R. L. LESTER: *J. Lipid Res.*, 5, 126–127 (1964).

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISÉE
Information seulement